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CIRCULATION AND DUST CONTENT OF THE VENUS ATMOSPHERE FROM WIND VELOCITY MEASUREMENTS BY THE VENERA-8 AUTOMATIC INTERPLANETARY PROBE

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16. Abstract

Measurement data of the horizontal component of the wind velocity on Venus during descent of the Venera-8 planetary probe are presented. The azimuth of the wind direction, counted off clockwise from the North pole direction, is approximately 115°, i.e.,the measured component was close to the zonal (latitudinal) one. The wind velocity comprised from 0.5 m/sec near the surface to 140/m/sec at altitudes of approximately 50 km. The general motion direction at all altitudes remains constant and coincides with the direction of Venus's rotation. Stable zonal motion of the (latitudinal) enveloping circulation type is believed to exist with a complex wind-velocity gradient increase with altitude. Dust content in the Venus atmosphere is discussed, and is shown to be low.

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CIRCULATION AND DUST CONTENT OF THE VENUS ATMOSPHERE FROM WIND VELOCITY MEASUREMENTS BY THE VENERA-8 AUTOMATIC INTERPLANETARY PROBE

V. V. Kerzhenovich and M. Ya. Marov

(Submitted by Academician A. P. Vinogradov, August 1, 1972)

During the descent of the land apparatus (LA) of the automatic interplanetary probe (AIP) Venera-8 preliminary estimates of wind velocity in the Venus atmosphere were conducted up to Doppler measurements of velocity in [1]. /554*

The component of wind velocity u_g in the direction from an "underground" point to the descent area was directly determined by the method utilized; the azimuth of this direction read clockwise from the direction to the North Pole, amounted to approximately -115°; i.e., the measured component was close to the zonal component. Measurements of velocity by the LA were characterized by the following errors: constant systematic error less than 0.2 m/s; slowly changing from 0 at the surface to 0.7 m/s at the start of measurements, fluctuating 0.1 m/s. Errors in estimating wind velocity were determined on the basis of inaccuracy of the descent velocity of the apparatus, calculated according to measurements of temperature, pressure, and altitude and amounted to from 0.5 m/4 at the surface to 7-8 m/s at altitudes close to 50 km.

The measured altitudinal distribution of wind velocity is depicted in Fig. 1a; wind velocity at altitudes of 0-12 km is depicted in Fig. 16. Curve a corresponds to the altitudinal referencing made according to temperature using a model of the atmosphere [2], and curve a corresponds to the altitude calculated by measurements of temperature and pressure using a hydrostatics equation. The horizontal lines correspond to the maximum error. The descent velocity of the LA for the profile in Fig. 16 was

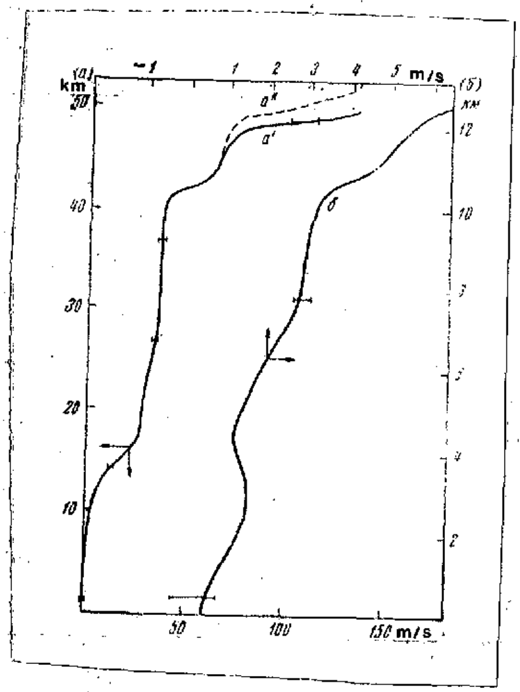
*Numbers in the margin indicate pagination in the foreign text.

obtained from approximations of measurements by a radio altimeter using a polynomial of the third degree.

Different magnitudes and directions of the wind velocity, such that their projection on the direction underground point--LA is equal to the measured component, can, in principle, correspond to the measured component. We are concerned in this observation with the measured component as well as with the wind velocity, recalling that the modulus of wind velocity can be even greater.

Wind velocity amounted to $0.5^{+0.25}_{-0.75}$ m/s at the surface and up to 140 m/s at altitudes near 50 km. The general direction of motion at all altitudes remained constant and corresponds to wind from the morning to terminator or from the bright side, i.e., it coincides with the direction of the proper rotation of Venus. The lower region of the higher wind velocity gradients (12-18 km) mainly lies below the boundary (~32 km) above which the noted contribution to the attenuation of solar radiation bears an aerosol component that can be associated with a possible spreading of the cloud cover [3].

A reduction of the measured component at altitudes of 42-50 and 12-18 km can also be connected with the wind rotation velocity; it being essential, however, that the measured values cannot correspond to a wind directed towards the proper rotation of Venus, as can be expected from the "depth circulation" model [4] or from numerical experiment [5].



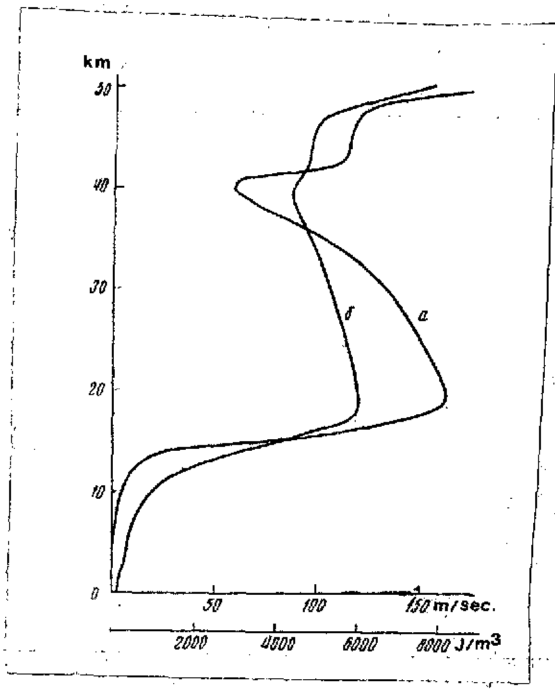


Fig. 1. Altitudinal distribution of wind velocity according to measurements by the AIP Venera-8; a - 0-52 km; 6 - 0 - 12 km.

Fig. 2. Kinetic energy of the atmosphere (a) and ground equivalent of wind velocity (b). /555

The average wind velocity energy was found as

$$\langle u\rangle=\left[\int_0^{H_0}\rho(h)\,u(h)\,dh \Big/ \int_0^{H_0}\rho(h)\,dh\right]^{1/2}, \tag{1}$$

where p(h) and U(h) are respectively the density of the atmosphere and the wind velocity at altitude h, which amounted to approximately 15 m/s and turned out to be close to the value on earth (17 m/s; g.v. [6]). This magnitude consderably exceeds estimates; at the same time, at altitudes of 0-10 km, where approximately one-half the mass of the atmosphere is concentrated, the average wind velocity has a magnitude on the order of 1 m/s, which coincides with previous estimates [7]. The relationship of kinetic energy to the enthalpy of an atmosphere column amounts to approximately $0.5 \cdot 10^{-3}$, which is also close to the value on earth.

The distribution of kinetic energy is depicted in Fig. 2 according to height and the "earth" equivalent of the measured wind velocity, whose magnitude was found as

$$\boxed{u_E = u(h) \cdot \left[\frac{\rho(h)}{\rho_0}\right]^{1/2},} \qquad (2)$$

where ρ_0 is the air density at the earth's surface. The maximum of the kinetic energy in the lower atmosphere is reached at an altitude of 18-20 km. The measured wind velocity at altitudes of 20-40 km is equivalent to 90-120 m/s at the earth's surface; 0.5 m/s at the surface of Venus corresponds to 3.5 m/s for the wind velocity on the earth.

Although the wind velocity measured on board Venera-8 exceeds data from Venera-4 and Venera-7 [8] (Venera-5 and Venera-6 meas- /556 ured only the vertical component), their results possess several several common features: the increase of wind velocity with altitude; the constancy of wind velocity in an altitudinal range of 20-40 km; and the smallness of the wind near the surface. In fact, the difference in the data from Venera-4, Venera-7, and Venera-8 is even less if we bear in mind the systematic error of the measurements of Venera-4 and Venera-7, and also the spread of the descent regions. It is also necessary to take into account that for Venera-4 the measured velocity component could correspond not only to the meridional movement, as was assumed in the initial interpretation, but also the zonal movement in the direction of the reverse rotation of Venus. Under these conditions, definite agreements of measurements which are illustrated in Figure 3, on which the measurement profiles of Venera-4 and Venera-7 are raised by an integer to magnitudes lying within the scope of the systematic errors, while for Venera-4, the velocity is given in a recalculation on the zonal component. Wind velocity corresponding to measurements on Venera-7 in a sector immediately after the start of signal reception from the descent apparatus (8:02:50 - 8:04:20) is depicted by a dotted line [15].

A comparison of the profiles obtained of wind velocity and directions of the measured components allow us to conclude that the circulation pattern of the Venusian atmosphere circulation pattern in the Venusian atmosphere can be noticeably different from both the "depth" circulation and the patterns obtained in numerical experiments. We may assume, given the limitation of our data and the possibility for superimposing of local phenomena, that circular motion in the equatorial zone of Venus coinciding with the direction of its proper rotation about the axis, is one of patterns that satisfy the measurements of the Venera series.

Investigations on the shifting of details on the Venus disc in ultraviolet light [9, 10] show that motion of a similar type apparently also holds true in the atmosphere at altitudes near 100 km. The wind velocity at these altitudes varies from 70 to 130 m/s with an average period of circulation of approximately 4.5 days. It is of interest that the wind velocity in the region where probes of the Venera-series began their measurements were shown to be close to characteristic values for four-day circulation. At altitudes of 20-40 km the circulation period can amount to twelve days or move. If such circulation is the true one, then the measurements of the Venera series relate to different sectors of the planet and reflect a longitudinal-time movement variability. Measurements of the differential Doppler shift of of the CO_2 band in the infrared region [11], referring again to the visible cloud cover ($\approx$60-70 km) attests to the possibility of movements with velocities up to 100 m/s at these altitudes as well.

It is possible to present a "wind model" of the equatorial zone of Venus in the form depicted in Fig. 4 by using the meas- /557 urements of the Venera series, data from ultraviolet photography, and spectroscopic measurements. The hatched regions correspond to the possible variations of wind velocity relating to the different measurements.

Steady-state zonal, circular motion-type movement, therefore, apparently takes place in the atmosphere of Venus, at least in a layer of up to 100 km over the surface, which is characterized by complex dependence of the increase of the wind velocity gradient on altitude. It is possible to hold to the belief that horizontal transport for a small velocity of the planet's proper rotation plays a significantly greater role in the smoothing out of nonequilibrium heating of its atmosphere due to the variation of the daily circulation than is the case on Earth, where the velocity of horizontal movement is usually less than 0.1Λ* and reaches 1.7-1.8Λ only in the thermosphere at altitudes of 300-350 km. On Venus this value is already reached at 10 km and in the neighborhood of 50 km amounts to approximately 50Λ. Unfortunately, very little is presently known regarding the support mechanism of the angular circulation. The counter-motion of a liquid liquid while a slowly rotating heat source warms it up, which was discovered [12], can serve as an experimental analogue, although the possibility of applying this analogue to the atmosphere of Venus

*Λ is the ratio of linear velocities of wind and planet surface.

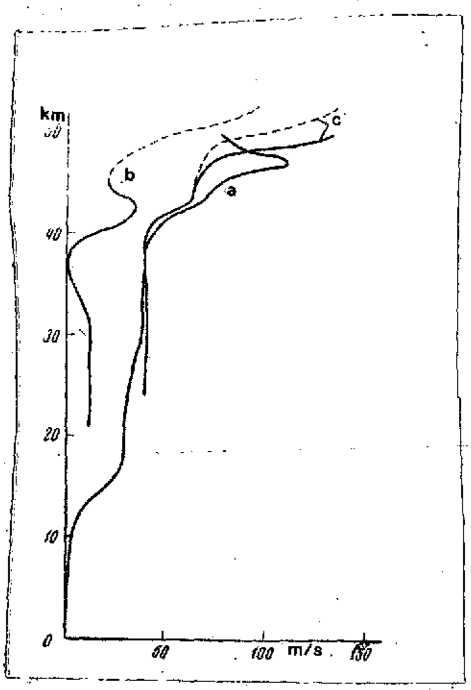


Fig. 3. A comparison of results of wind velocity measurements on the AIP Venera-4 (a); Venera-7 (b); and Venera-8 (c).

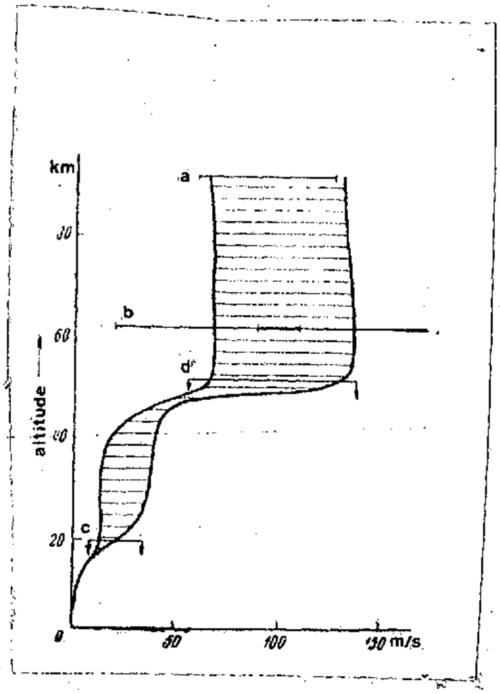


Fig. 4. "Wind model" of the Venus atmosphere: (a) ultraviolet photography; (b) spectroscopic measurements; (c) Venera-8; (d) Venera 4, 7, 8.

requires additional theoretical and experimental corroboration.

The study of profiles of wind velocity near the surface leads to an important consequence. It was believed until recently that Venus' dry atmosphere could hold much dust. Volcanic activity, dust from cosmic sources, and wind erosion serve as dust sources on a planet. The absence of moisture, of contributing purification of the atmosphere, and the formation of related compounds is a factor that is favorable for the process in which dust appears. Moreover, this factor, together with a constancy in temperature at the surface can be considered as an argument against a large quantity of dust, since the presence of moisture and temperature contrasts facilitates the destruction of surface rock. The upper limit of SO, content in the atmosphere of Venus, measured from Earth, can be interpreted as an indicator for volcanic activity not leading to the noted dust content [13]. If we now compare measurements of wind velocity near the surface, generated by Venera-8, with estimates of wind erosion processes on Venus, as presented in [14], it is possible to conclude that wind velocity at the surface turns out to be insufficient for lifting isolated particles, disregarding again abrasive erosion.

The small dust content of the Venus atmosphere is emphasized by direct measurements of illumination conducted onboard AIP Venera-8, which demonstrated that the atmosphere lower than 32 km is practically free of aerosoles. The adiabatic course of the temperature down to the surface itself is attested to by the comparatively small dust content.

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